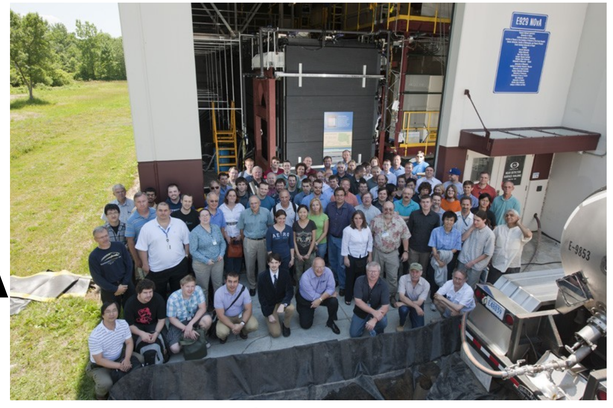
Track and Vertex Reconstruction for NOνA



110 physicists from 24 institutions 4 countries

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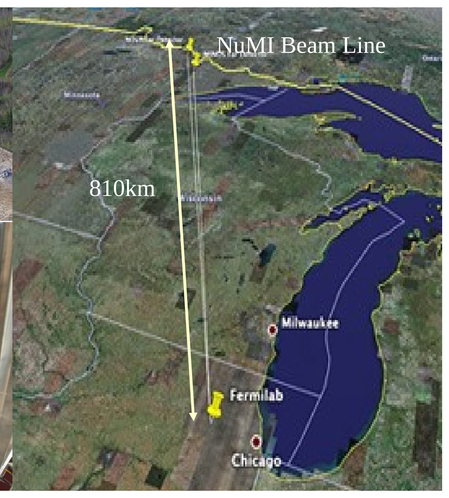
General Introduction to NOνA

The NOνA (NuMI Off-axis ν_e Appearance) experiment is a two-detector long baseline experiment searching for electron neutrino appearance in the NuMI (Neutrinos at the Main Injector) muon neutrino (~2 GeV) and antineutrino beams. The near detector is being set up at Fermilab and the far detector is under construction in Ash River, Minnesota.



Motivations & Goals

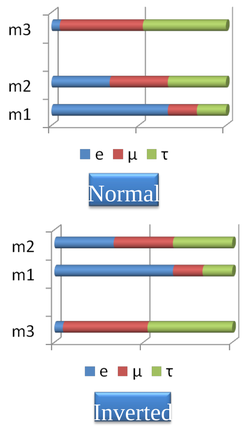
Measuring θ_{13}:

This parameter is small. Is it non-zero?

Determine Mass Hierarchy:

Two possible mass hierarchies:

1. A "normal" order has two light mass states and one heavy state



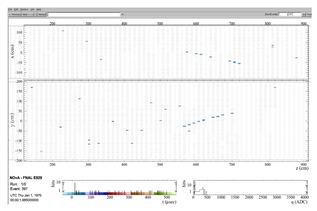
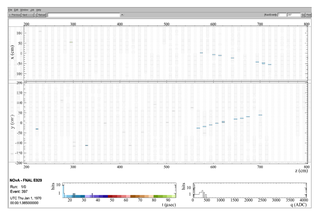
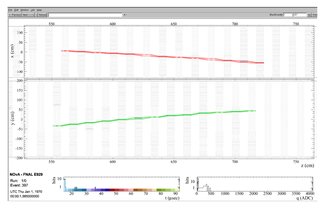
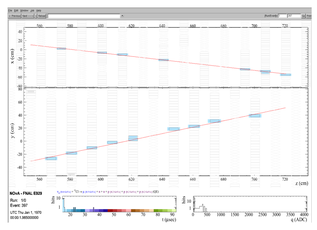
2. An "inverted" order has one light mass state and two heavy states

Constrain CP Violation Phase:

$\nu_\mu \rightarrow \nu_e$ occurrence would open the avenue to measure CP violation in the neutrino sector.

Track Reconstruction

We have made progress in developing our NOνA reconstruction software. Track and vertex reconstruction modules are currently based on a module which uses Hough Transform. Vertex reconstruction is based on the information produced by previous modules responsible for track reconstruction.

Description	Logic Flow Chart of Track Reconstruction	Monte Carlo Muon neutrino charged current quasi-elastic event
In the beginning of the module, we include purifying process excluding the noise cell hits via choosing right time slices and applying photoelectrons lower number cut .	Raw Cell Hits → Selected Cell Hits	
Make 2D Clusters in both *xz* and *yz* views that come from the Hough Transform	Selected Cell Hits → Merged Cluster	
Take the results from previous module and refine them by merging small and inaccurate clusters into 2D tracks	Merged Cluster → Merged Track	
Match the 2D tracks in *xz* and *yz* views and finally produce 3D tracks.	Merged Track	

Track Evaluation

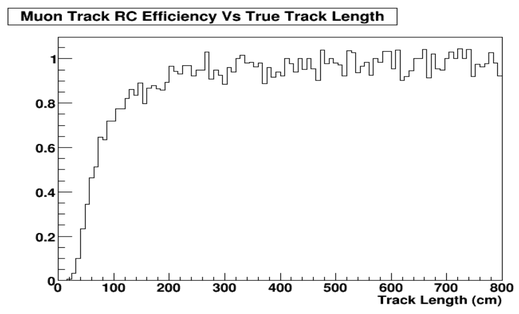
We also have evaluated the track reconstruction efficiency and quality. Here are some evaluation results for muon track reconstruction of Monte Carlo ν_μ CCQE (charged current quasi elastic) events.

Track Matching

Define:
Matching Purity = Cell Hits caused by the particle/ Total number of Cell Hits in the reconstructed track

This is the key parameter to identify a reconstructed track, by default we require a matching purity above 50%.

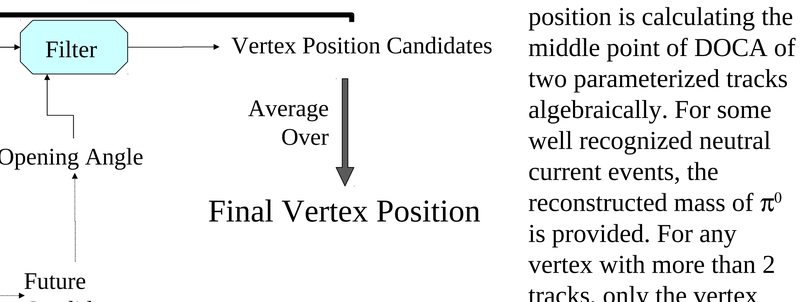
Track Reconstruction Efficiency



The reconstruction efficiency trend as a function of track length

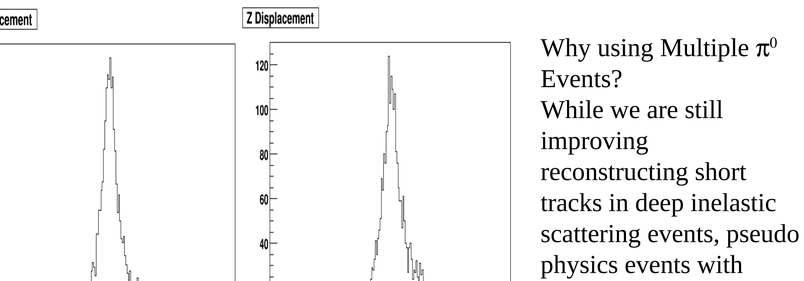
Track Reconstruction Quality

Track Length



The left plot is the muon track length (inside the detector) distribution generated with Monte Carlo truth. The right plot gives the difference of reconstructed track length and true track length inside the detector.

Energy Deposition

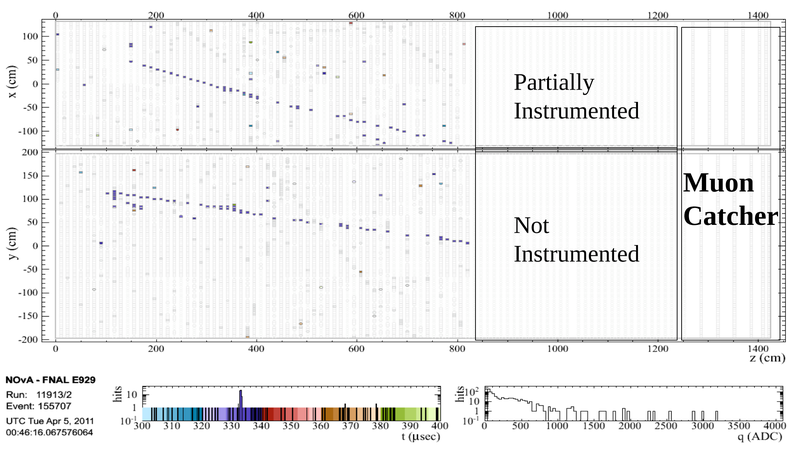


The left plot shows the Monte Carlo truth energy spectrum of the muons. The right plot is the difference between the calibrated energy deposited in the NDOS (muon catcher excluded) and the true kinetic energy of the muon.

Detector Status

The Near Detector On the Surface (NDOS) is the prototype Near Detector. It is functionally identical to the ND and has been operating on the surface at Fermilab and taking neutrino data since October 2010.

75% of the NDOS has been instrumented with readout channels.

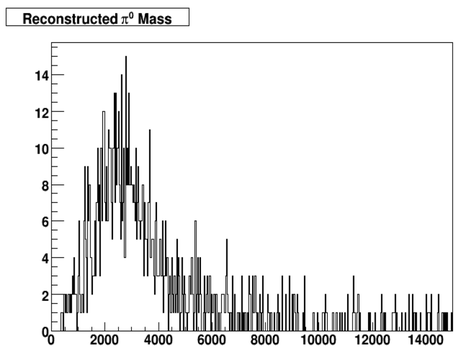


Candidate ν_μ Charged Current Event , from NDOS this June

Vertex Reconstruction Method and Results

The algorithm of reconstructing the vertex position is calculating the middle point of DOCA of two parameterized tracks algebraically. For some well recognized neutral current events, the reconstructed mass of π^0 is provided. For any vertex with more than 2 tracks, only the vertex position is reconstructed.

Vertex Position Deviation Test with Multiple π^0 Events



Mass reconstruction in raw ADC units for simulated 1.0 GeV single π^0 particles

We simulated 10,000 1.0 GeV π^0 particles with the same initial position and the momenta isotropically distributed, and then reconstructed the position from the photon tracks and electron showers generated by these π^0 particles

Why using Multiple π^0 Events?
While we are still improving reconstructing short tracks in deep inelastic scattering events, pseudo physics events with multiple tracks like triple 1.0 GeV π^0 events are simulated to test the vertex finding algorithm.